

A Brief Introduction to Remote Sensing for Air Quality Applications

NASA ARSET- AQ Webinar Course
Winter 2014

Course Instructors:

Rich Kleidman
Pawan Gupta
Jacquie Witte

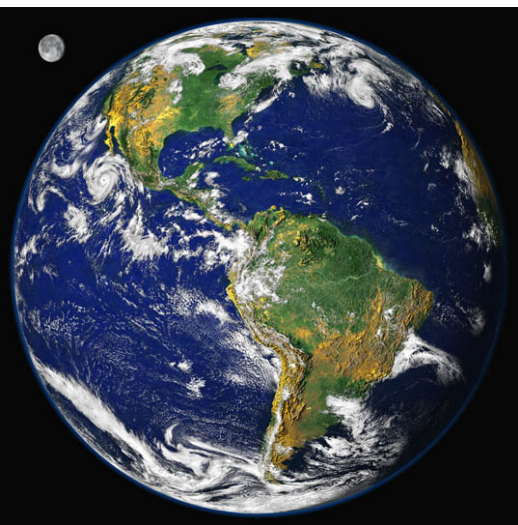
ARSET - AQ

Applied Remote Sensing Training – Air Quality

A project of NASA Applied Sciences



Week 1



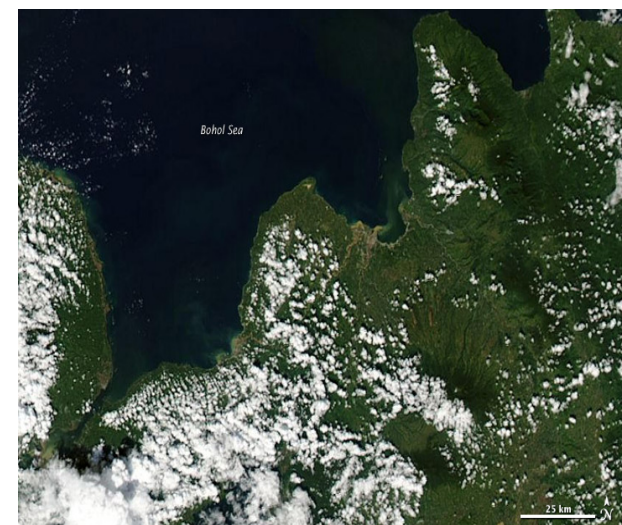
Introduction

Week 2



Satellites & Sensors

Week 3



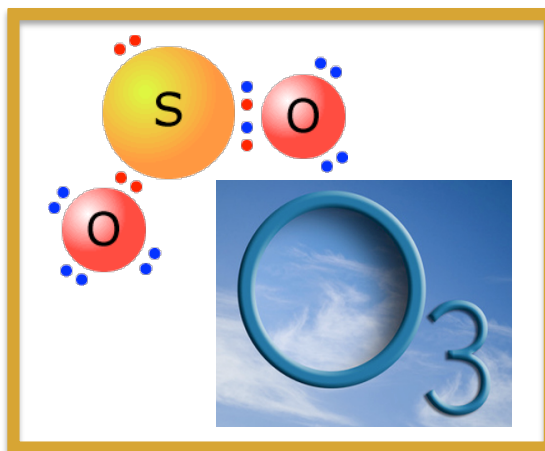
Imagery

Week 4



Aerosols

Week 5



Trace Gases - 1

Week 6



Trace Gases - 2

Introduction

Week 1

Outline:

1. The ARSET training program
2. Course Overview
3. Pros and cons of remote sensing for air quality work
4. Essential information for any remote sensing product
5. Assignment

NASA and Earth Science

Applied Sciences Program

Applications to Decision Making: Eight Thematic Areas



**Agricultural
Efficiency**



Air Quality



Climate



**Disaster
Management**



**Ecological
Forecasting**



Public Health



**Water
Resources**



**Weather
(Aviation)**

Who are we training ?

- **Air Quality Managers and Regulators**
EPA, state and local regulatory agencies, US Forest Service
- **Scientists/Technical:** Meteorologists, air quality forecasters and modelers, health scientists, AQ researchers
- **Other/public:** project managers, reps. from health agencies, World Bank

Expertise

ANY Audience can span a large range in expertise:

- **No background in remote sensing** and little science background
- **No background in remote sensing and some science background**
- **Introductory expertise** with satellite data
- **Moderate expertise** with satellite data

There is a lot to learn.



Take it one step at a time.

What Level of Knowledge Do You Need?



Awareness

Competence

Expertise

Some Things We Want to Know About Aerosols and Trace Gasses for Air Quality Applications.



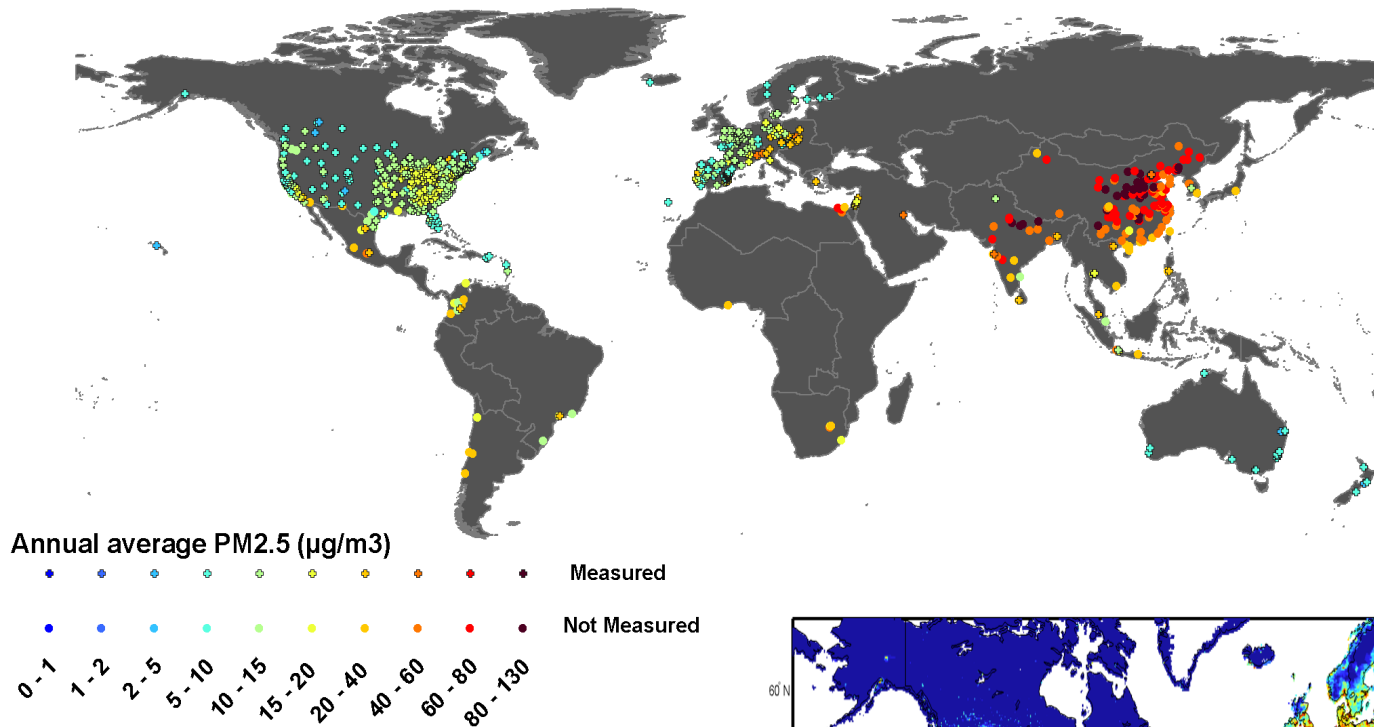
Sources and sinks

Concentrations at the ground

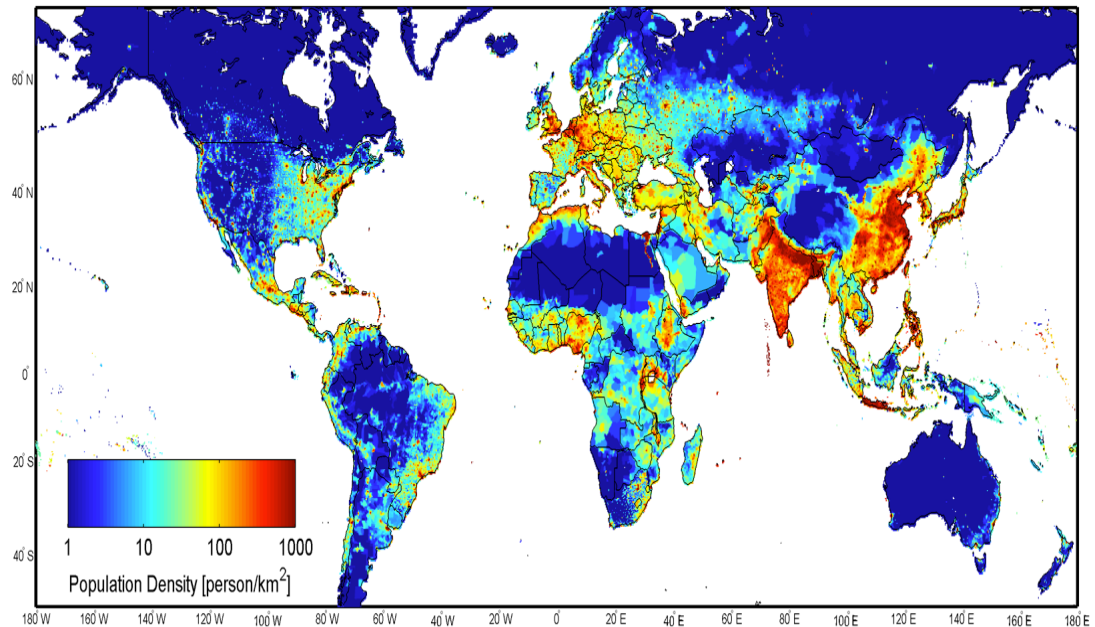


Human exposure estimates

Global Status of PM2.5 Monitoring Networks

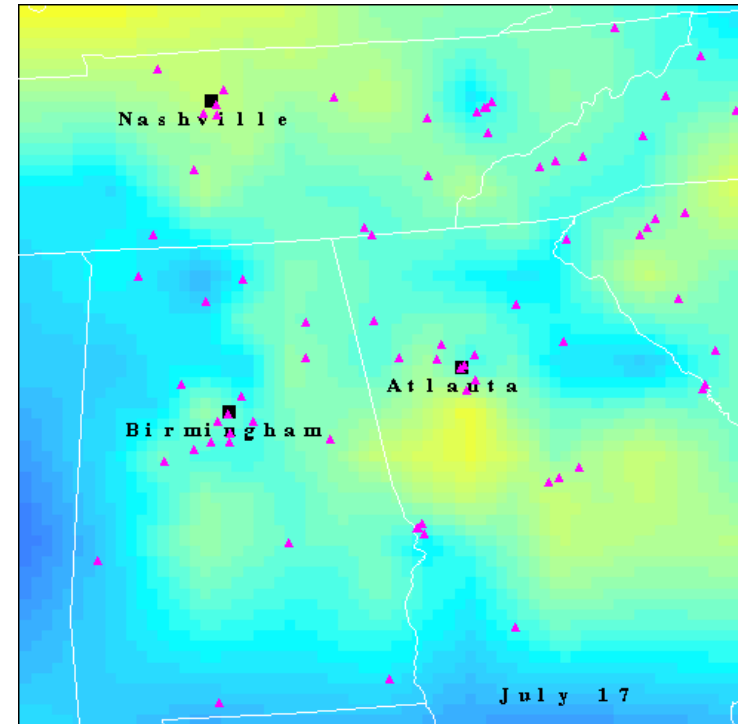
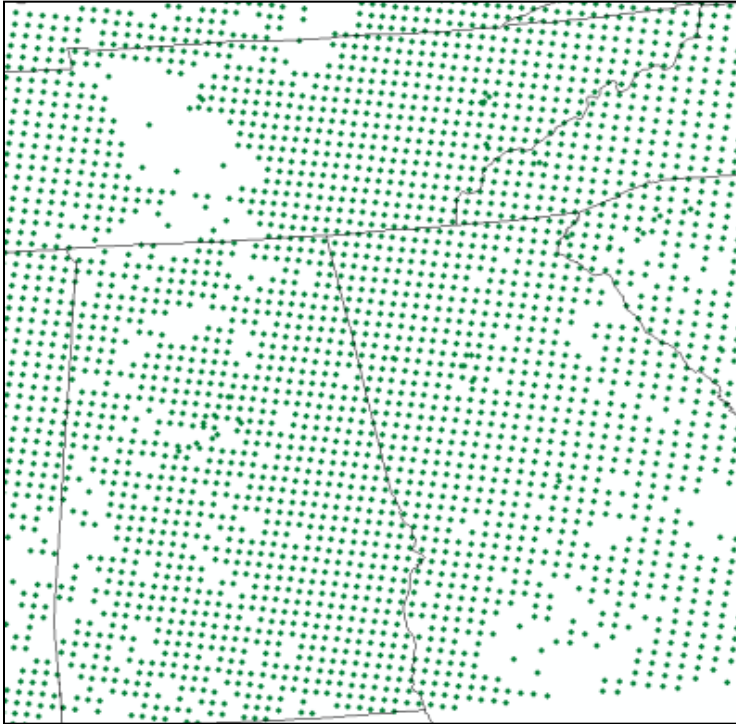


Brauer M, Ammann M, Burnett R et al.
GBD 2010 Outdoor Air Pollution Expert Group
2011 Submitted—under review



Why Use Remote Sensing Data?

Spatial Coverage

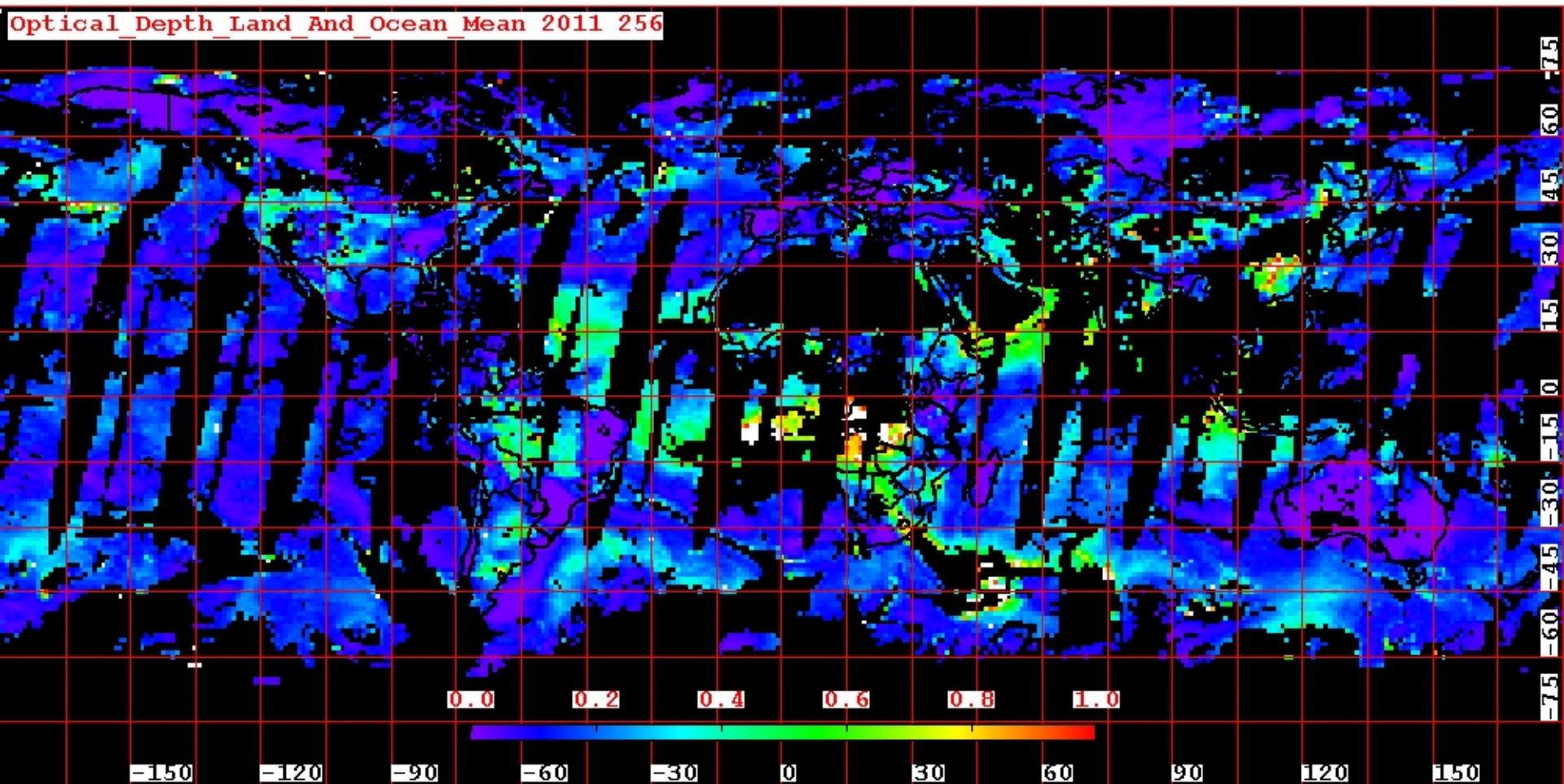


 - Satellite (MODIS) Retrieval Locations
White Areas – No Data
(Most likely due to clouds)

 – Ground Monitors

Spatial Coverage

MODIS One Day Aerosol Product Coverage



Satellite Products for Air Quality Applications

- **Particulate Pollution** (dust, haze, smoke)
 - Qualitative: Visual imagery
 - Quantitative*: Atmospheric Column Products
- **Fire Products:** Fire locations or ‘hot spots’
Fire radiative power
- **Trace Gases**
 - Quantitative*: Column Products
 - Vertical profiles: mostly mid-troposphere
 - Some layer products

Earth Satellite Observations

Advantages and Limitations



Satellites Vs Sensors

Earth-observing satellite remote sensing instruments are named according to

- 1) the satellite (also called platform)
- 2) the instrument (also called sensor)

Aqua Satellite



Six Instruments:

- MODIS
- CERES
- AIRS
- AMSU-A
- AMSR-E
- HSB

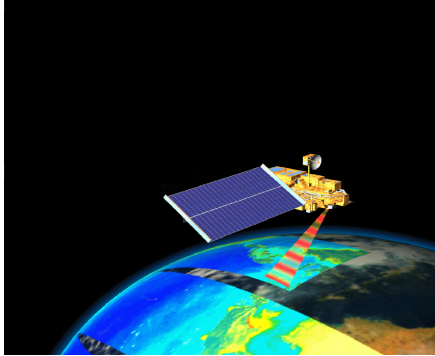
Aura Satellite



Four Instruments:

- OMI
- TES
- HIRDLS
- MLS

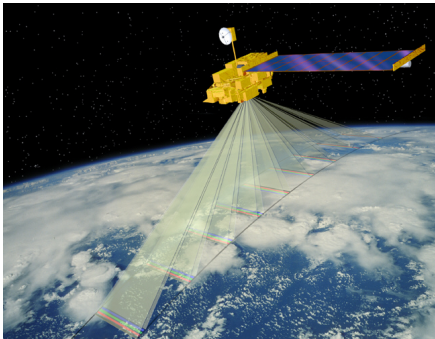
Primary Sensors - AEROSOLS



MODIS

MODerate resolution **Imaging SpectroRadiometer**

Measures total column aerosol
AOD - Aerosol Optical Depth



MISR

Multi-angle Imaging SpectroRadiometer

AOD
Particle Type

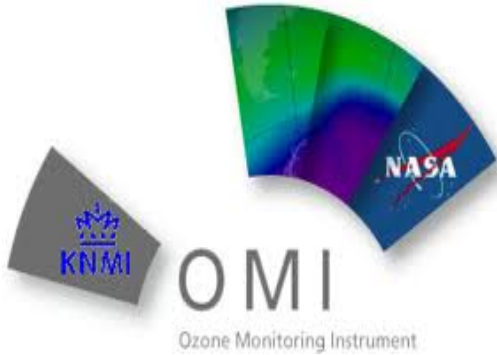


VIIRS

Visible Infrared Imaging Radiometer Suite

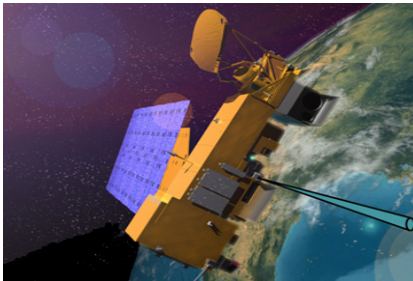
AOD
Particle Type

Primary Sensors – Trace Gases



OMI

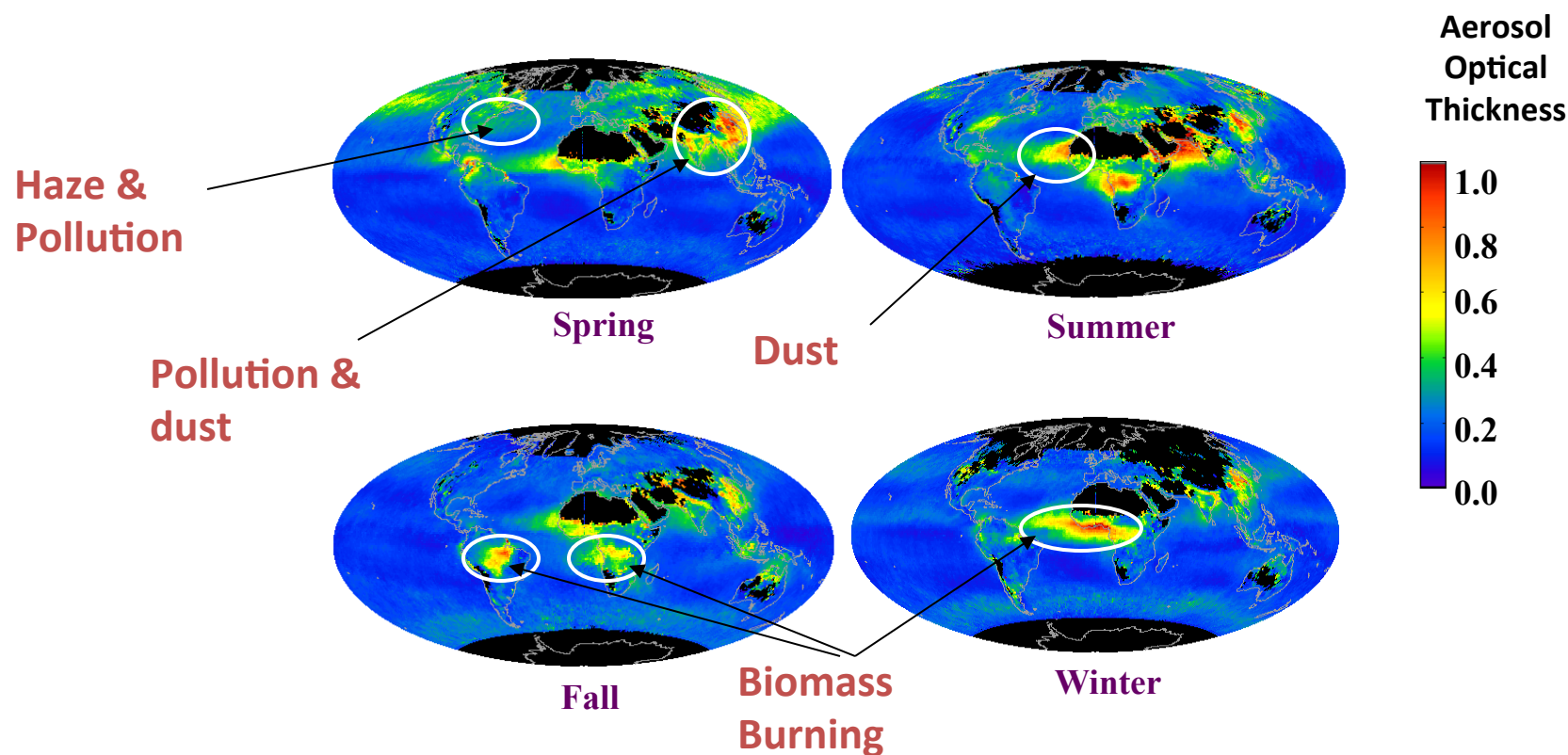
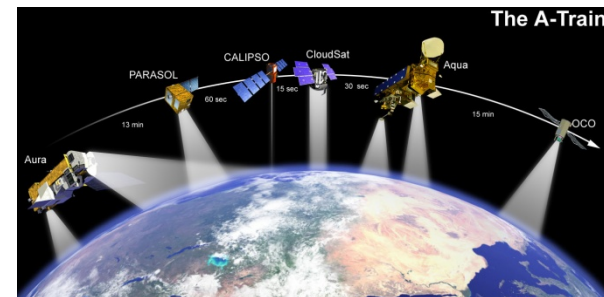
Ozone Monitoring Instrument



AIRS

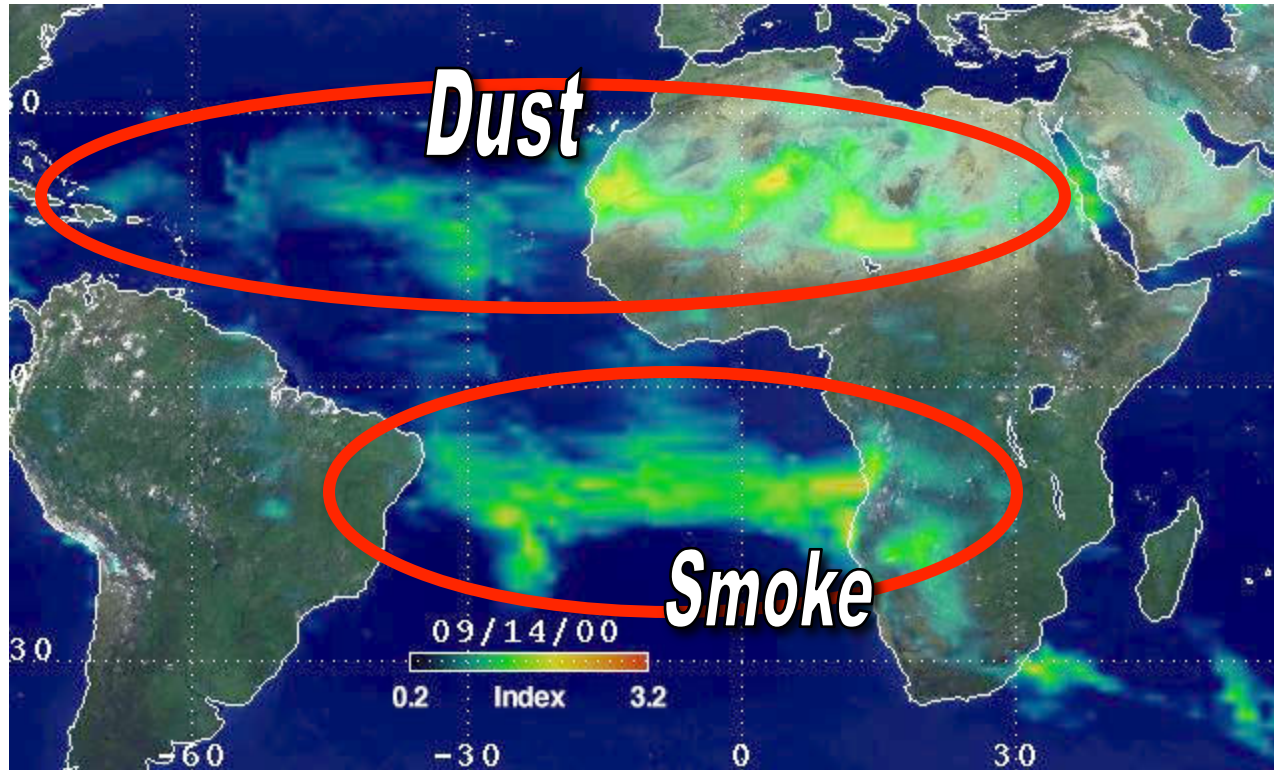
Atmosphere Infrared Sounder

Some kinds of aerosol data available from satellite.



Several satellites provide state-of-art aerosol measurements over global region on daily basis

Global Coverage Helps Us to Estimate Transport and Source Regions



Aerosols Transported Across the Atlantic

Earth Satellite Observations

Advantages

Air Quality/Pollution

- Provides coverage where there are no ground monitors
- Synoptic and trans-boundary view (time and space)
- Visual context
- Qualitative assessments and indications of long range transport
- **Adds value when combined with surface monitors and models**

Earth Satellite Observations

Limitations

I'm Going to
Need a Better
Telescope



Earth Satellite Observations

Limitations

1. Temporal Coverage



2. Vertical Resolution of Pollutants



3. Lack of Near Surface Sensitivity

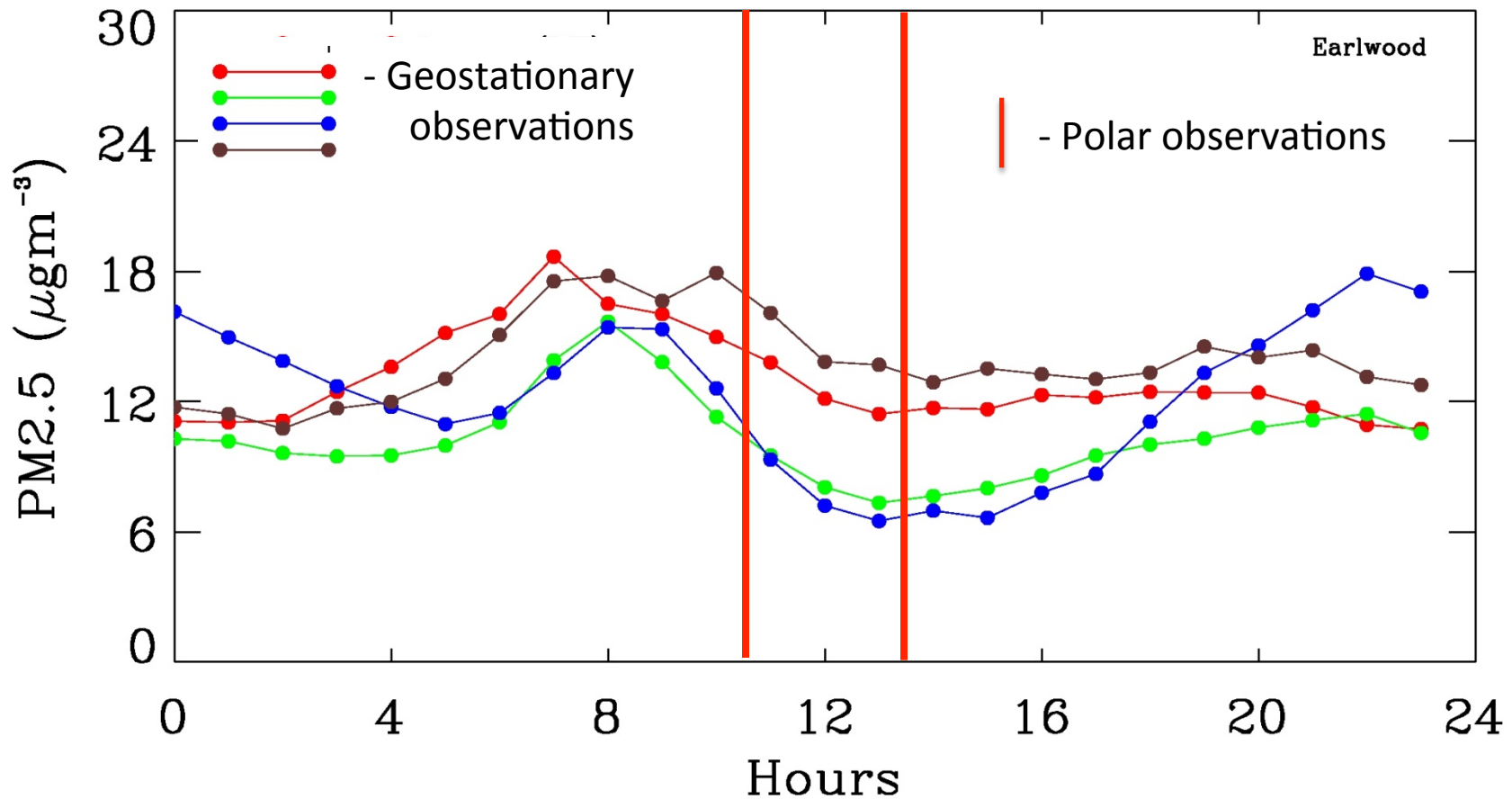


4. Lack of specific identification of pollutant type



Temporal Coverage

Polar orbiting satellites – 1 - 2 observations per day per sensor



Geostationary satellites – product quality is lacking in many locations

Limitations of Satellite Data

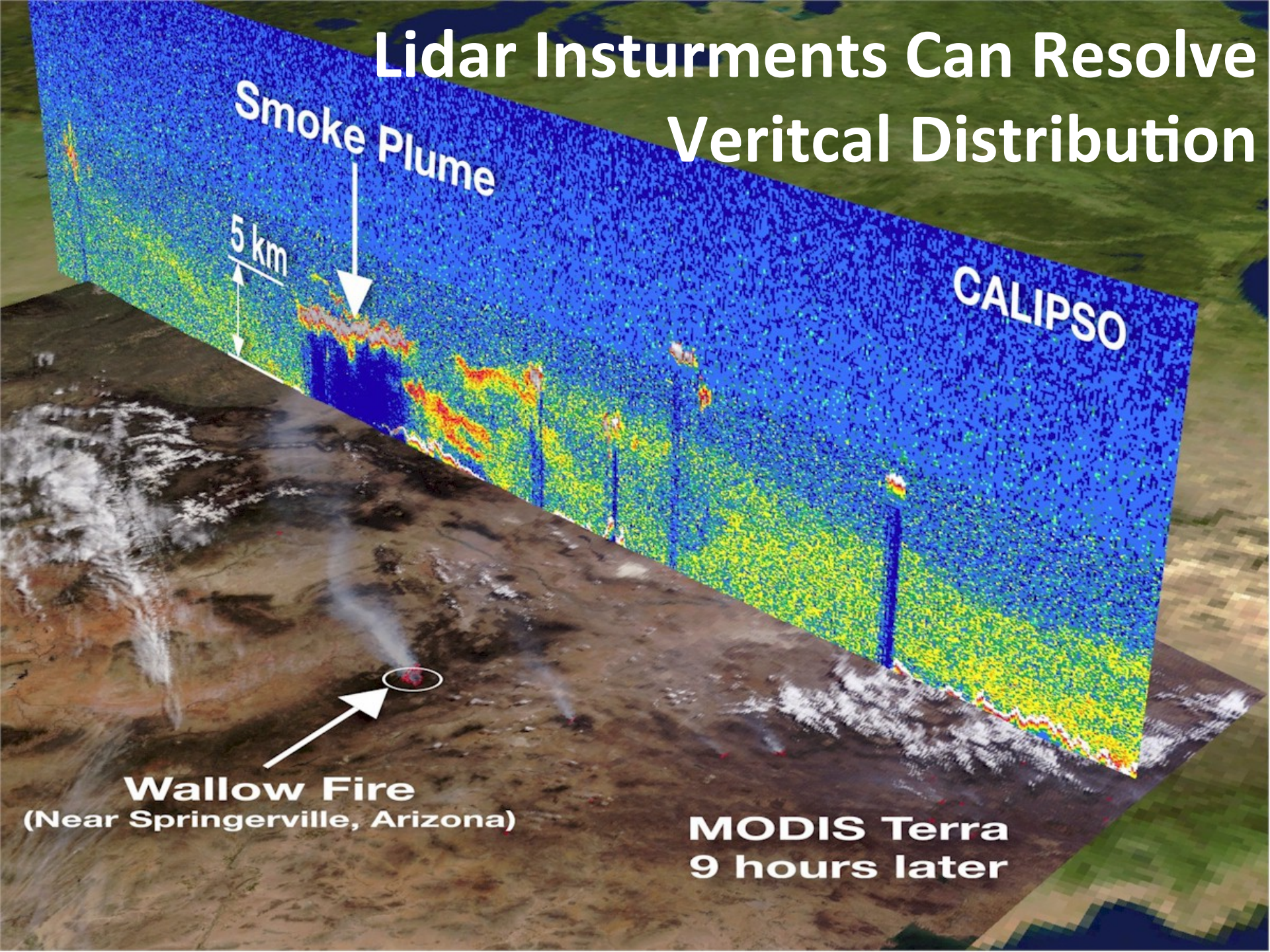
Almost all satellite sensors are **passive sensors**.

Passive sensors measure the entire column.

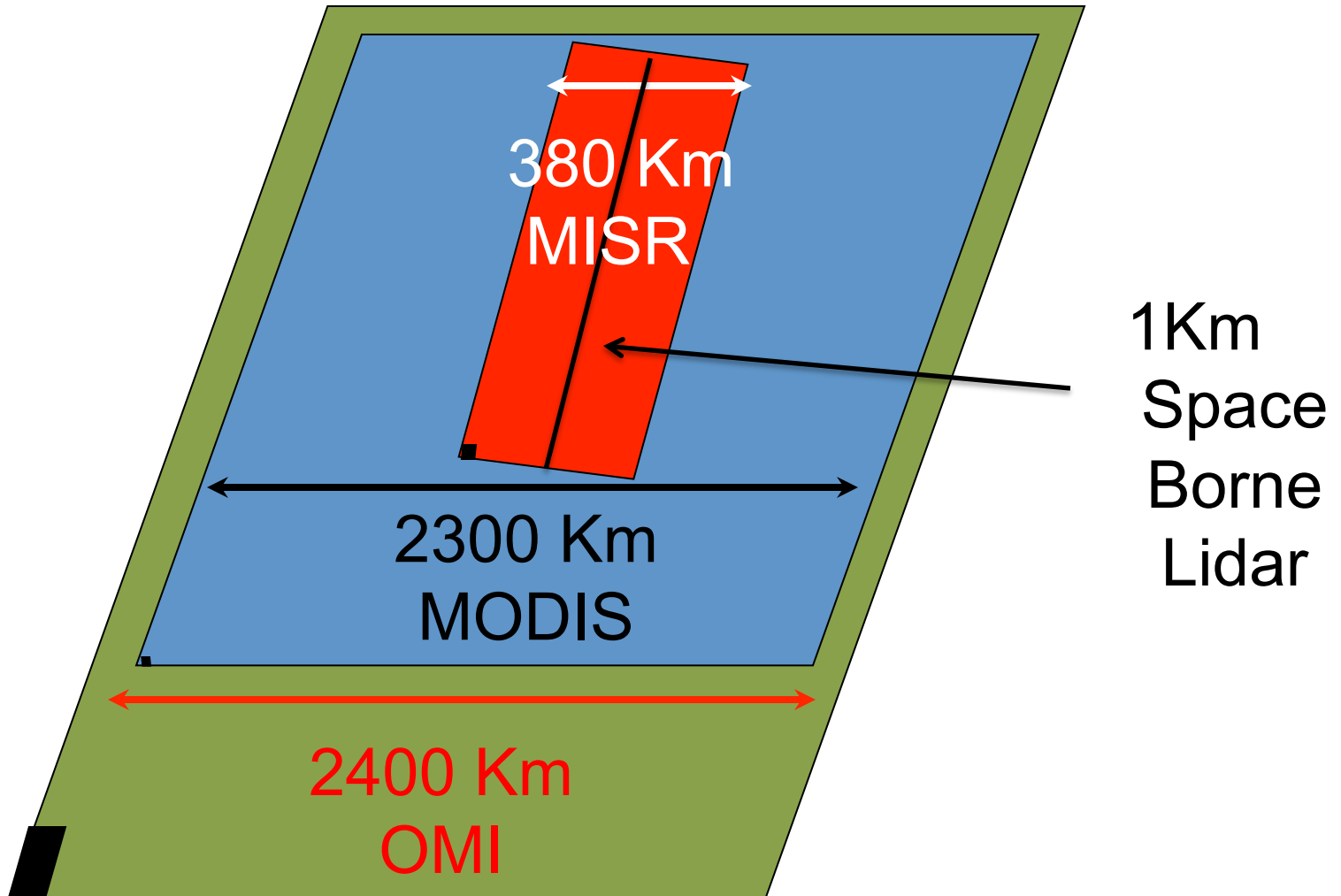
Column measurements may or may not reflect what is happening at ground level.

This is true whether we are measuring aerosols or trace gasses.

Lidar Instruments Can Resolve Vertical Distribution



Principal Satellites in Air Quality Remote Sensing



Earth Satellite Observations

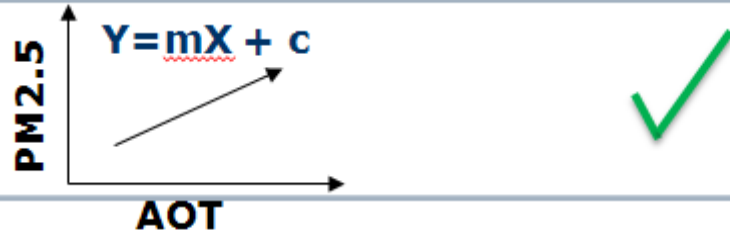
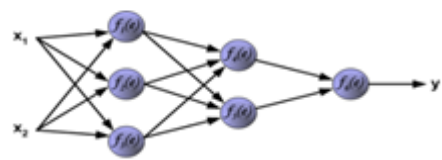
Limitations

Air Quality/Pollution

- Lack of specificity about pollutant types
- Resolution and temporal scales sometimes too coarse
- Vertical distribution often unknown
- Satellite data **cannot be used quantitatively for enforcement purposes** such as for example to determine whether a region is in attainment or not (Hoff and Christopher 2009).

**Can we overcome the limitations of
satellite measurements in determining
ground level exposure to pollutants ?**

PM2.5 Estimation: Popular Methods

Two Variable Method		
Multi Variable Method		$PM2.5 = \beta_0 + \alpha * \tau + \sum_{n=1}^m (\beta_n * M_n)$
Neural Network		
Model + Satellite		$\text{Estimated } PM_{2.5} = \frac{\text{Model surface aerosol concentration}}{\text{Model AOD} \times \text{Retrieved AOD}}$

and Empirical Methods, Data Assimilation etc. are under utilized

Satellite Measurements Probably Can Be Used to Determine Exposure Categories

Index Values	Category	Cautionary Statements	PM _{2.5} (ug/m ³)	PM ₁₀ (ug/m ³)
0-50	Good	None	0-15.4	0-54
51-100	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion	15.5-40.4	55-154
101-150	Unhealthy for Sensitive Groups	Sensitive groups should reduce prolonged or heavy exertion	40.5-65.4	155-254
151-200	Unhealthy	Sensitive groups should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion	65.5-150.4	255-354
201-300	Very Unhealthy	Sensitive groups should avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion	150.5-250.4	355-424

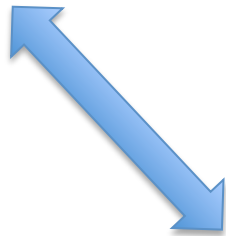
The Highest Quality of Data Rests on a Tripod



Satellite
Data



Ground Measurements
and In-Situ Data



Models



A Brief Pause for Questions

Practical Steps to Using



Remote Sensing Products



Data Archives

Tools



To Prepare Data



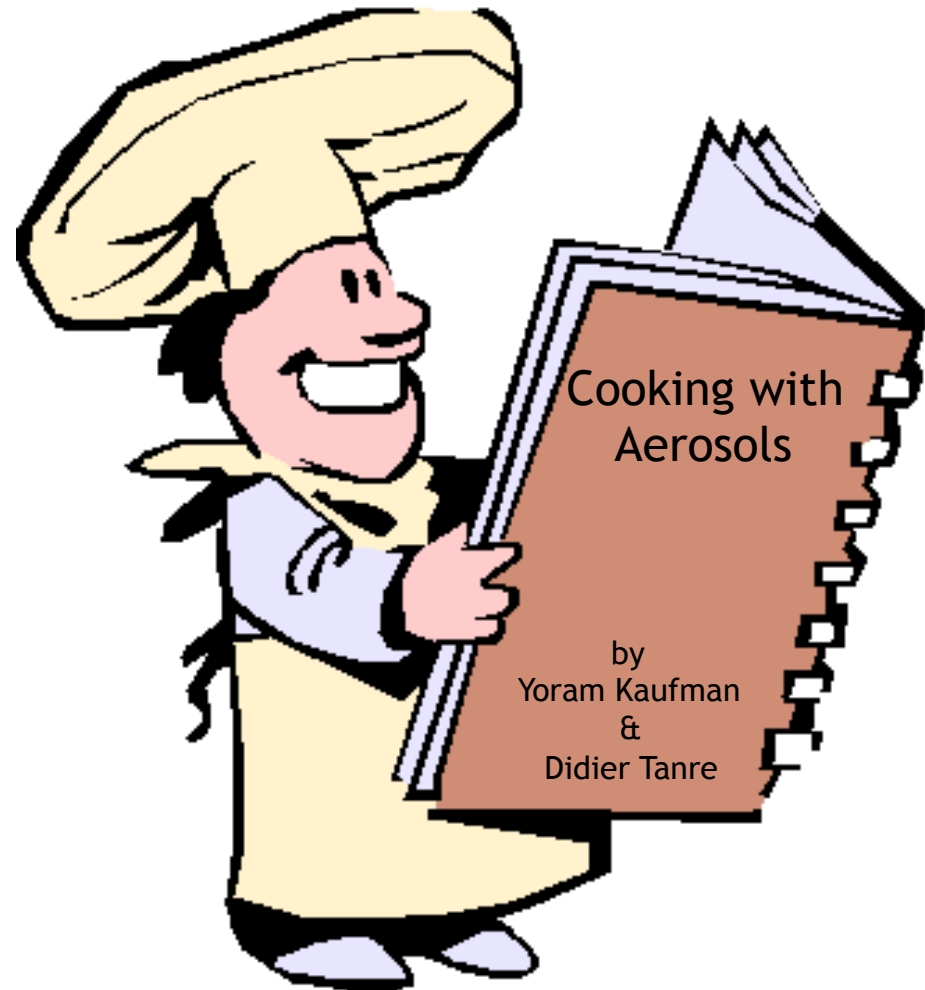
To Use Data

Web Based and Stand Alone Tools

Remote Sensing Science



Algorithms



Complementary Data

Related Products, Ground Based Data, Meteorological Data

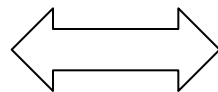
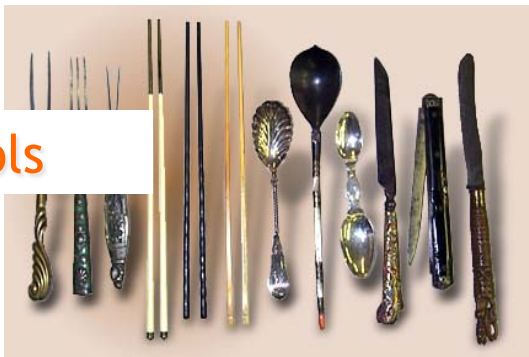


Often used to obtain more information or for validation



GIOVANNI, RSIG

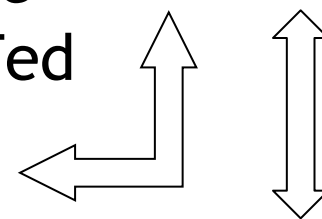
Tools



Archives



LADSWEB
Lance
Data Fed



Remote Sensing Products



MODIS Aerosols

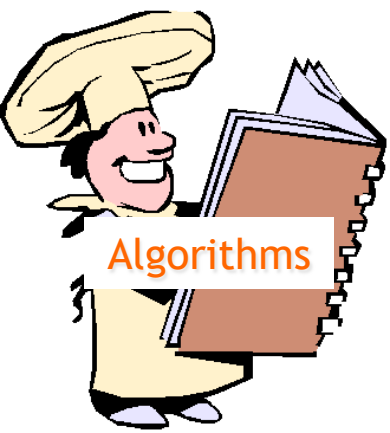
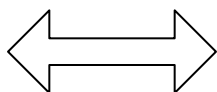


Complementary Data
AERONET



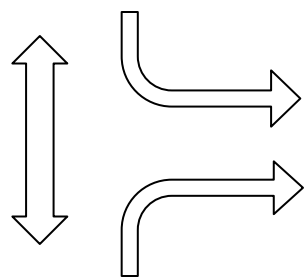
Remote Sensing Science

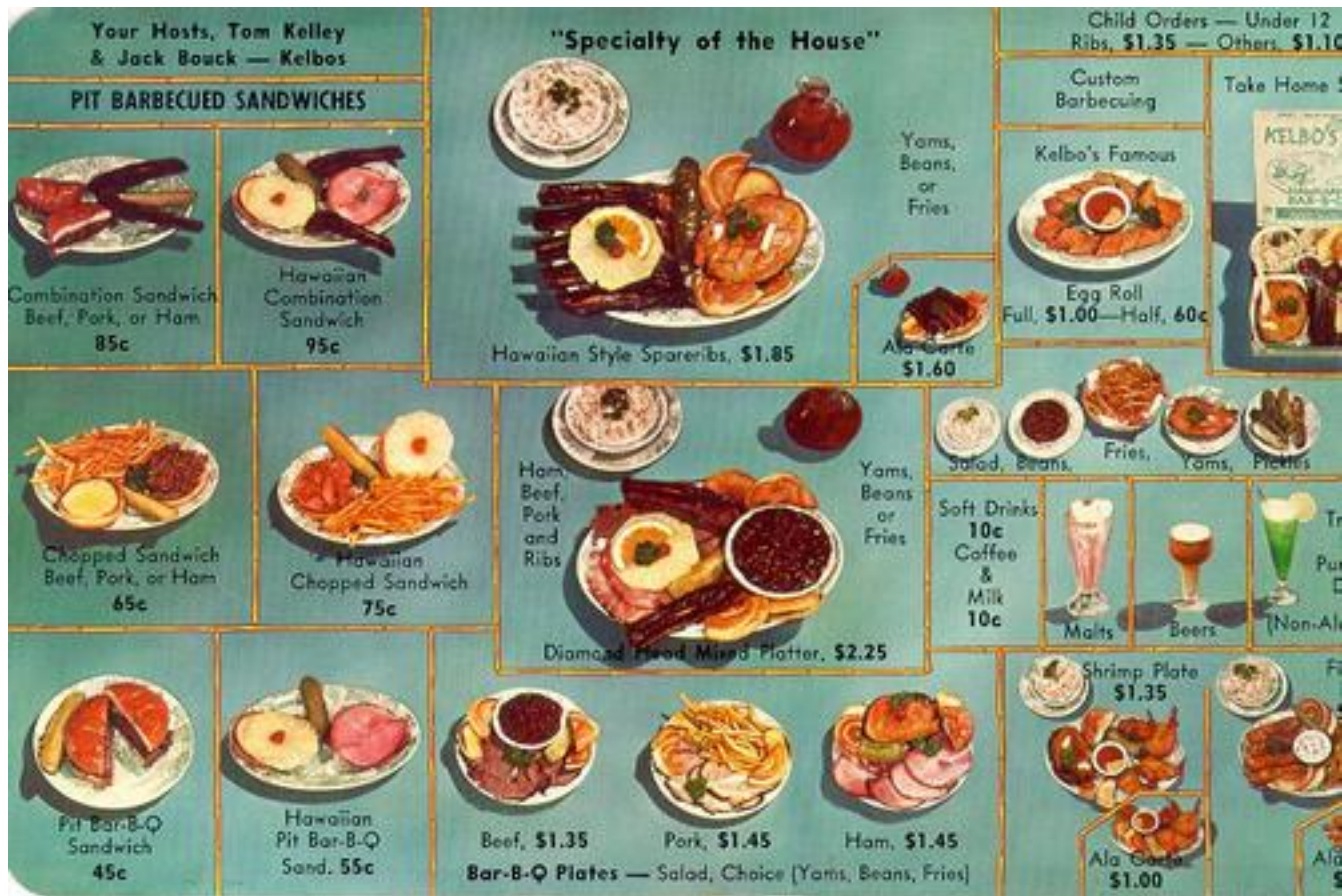
Orbits, sensors, spectra,
radiative transfer



Algorithms

MODIS Ocean,
Land, Deep Blue





Many Remote Sensing Products
MISR, OMI, Calipso, GOES

And It's All Free!



Know Your Data Sets
Know Your Tools



Know Your Data Experts!

A Brief Tour of the ARSET – AQ Website

<http://airquality.gsfc.nasa.gov>

The screenshot shows a web browser window with the title "ARSET: Air Quality". The address bar displays "http://airquality.gsfc.nasa.gov/". The page features the NASA logo and "National Aeronautics & Space Administration Goddard Space Flight Center" in the header. A search bar labeled "Search SED Site" with a "GO" button is present. Below the header, a banner image shows a satellite view of Earth with the text "Applied Remote Sensing Education & Training Air Quality". A left sidebar contains a navigation menu with links: Home, Training Materials, Courses & Workshops, Air Quality Case Studies, Project Consultants, Links, Calendar, Publications, Personnel, and Tools. The main content area is titled "ARSET: Air Quality" and contains a paragraph about the project's goal, a list of activities, and a description of project courses. A right sidebar includes "ARSET Email Alerts" with a sign-up prompt and "Scheduled Trainings" listing two events: "NASA Pre-workshop Training" and "NASA Training for Canadian Applied Science Professionals".

ARSET: Air Quality

http://airquality.gsfc.nasa.gov/

NASA National Aeronautics & Space Administration Goddard Space Flight Center

Search SED Site GO

Flight Projects | Sciences and Exploration

Applied Remote Sensing Education & Training
Air Quality

Home

- ▶ Training Materials
- ▶ Courses & Workshops
- ▶ Air Quality Case Studies
- Project Consultants
- Links
- Calendar
- Publications
- ▶ Personnel
- Tools

ARSET: Air Quality

The goal of the NASA Applied Remote Sensing Education and Training (ARSET) air quality project is to increase the utility of NASA earth science and model data for policy makers, regulatory agencies, and other applied science professionals in the area of air quality applications. The two main activities of this project are:

- Provide in-person and on-line courses, workshops and other capacity building activities throughout the year.
- Disseminate via this web page course materials and other information to enable training in applied air quality remote sensing.

Project courses are a combination of lectures and computer hands-on activities that teach professionals how to access, interpret, and apply NASA aerosol and trace gas data at regional and global scales with an emphasis on case studies. Course topics include:

- ▶ Case Studies in air quality analysis tailored to end-user needs, such as urban air pollution, dust, and fires.
- ▶ Satellite aerosol and trace gas products, their application and relationship to in-situ monitor data.
- ▶ Long Range Transport of atmospheric aerosols (or particulate matter) and

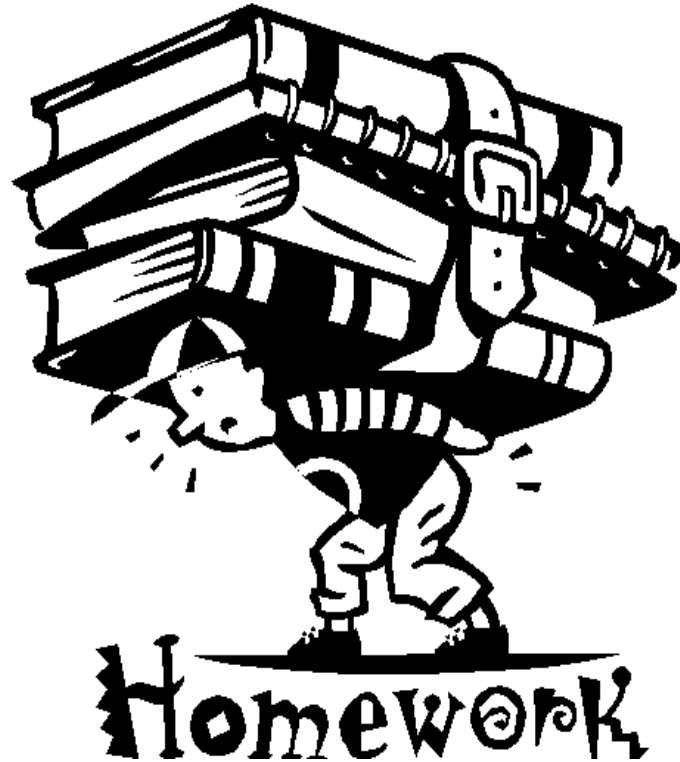
ARSET Email Alerts

If you would like to be informed of new materials and upcoming workshops please sign up for our list serv.

Scheduled Trainings

- ▶ **NASA Pre-workshop Training** International Society of Exposure Science Baltimore, Maryland October 23, 2011 [registration \(leaving NASA\)](#)
- ▶ **NASA Training for Canadian Applied Science Professionals** Quebec, Canada

Assignment



<http://airquality.gsfc.nasa.gov/index.php?section=25>

Assignment #1 Due Before Session 2 on Wed July 31, 2013.



**Comments
please!**

Your input is very important to us.
Please let us know how we can do a better job.